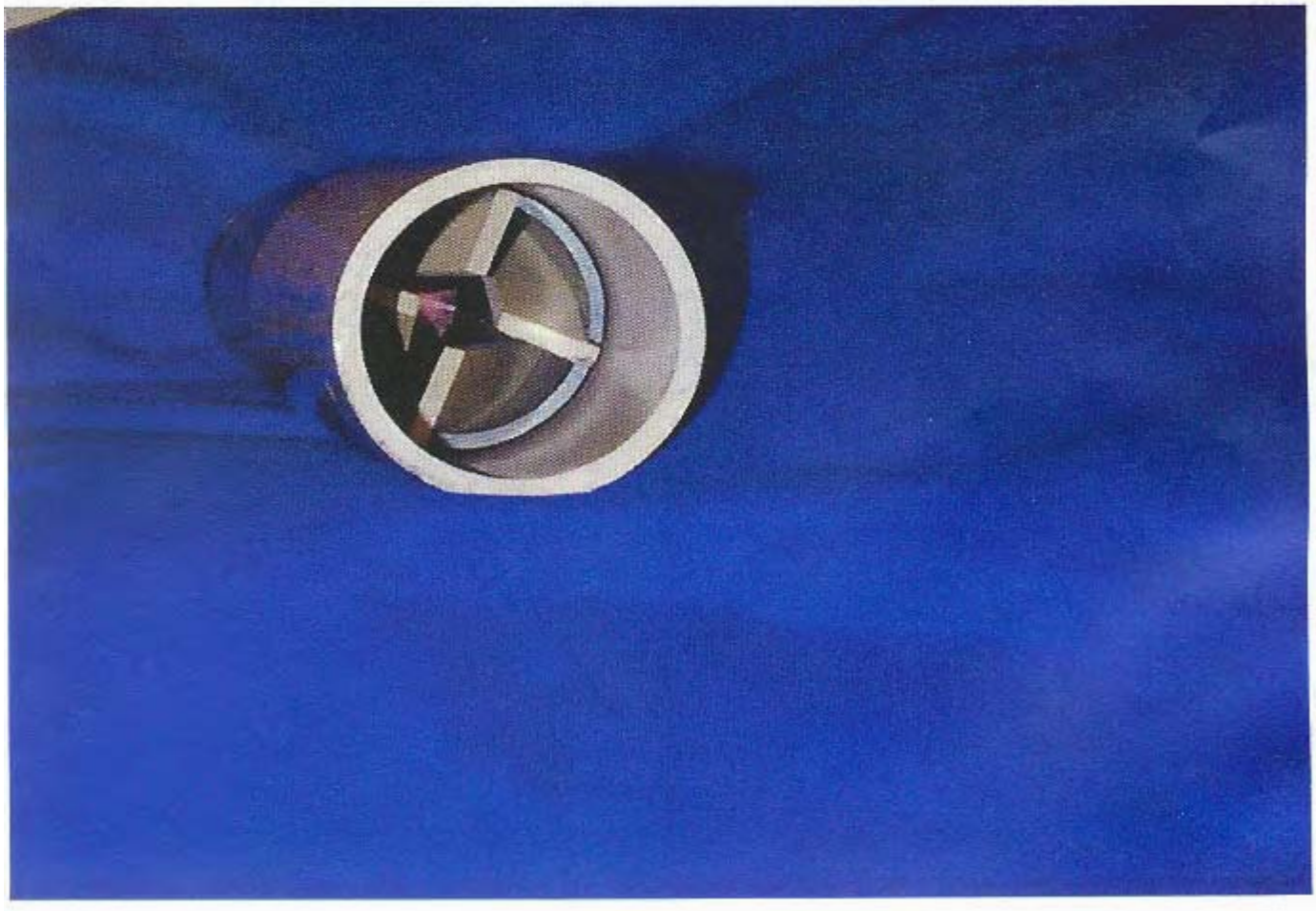
Adiabatic Expansion Nozzle

Technology

for

Fire Extinguishers



Introduction

The National Fire Protection Association (NFPA) reported that the 4,035 deaths by fire in 1998 represented the lowest U.S. fire death toll in 20 years. The report also noted that the total number of fires and fire-related injuries have also decreased significantly since 1980. However, there were still 1,755,500 fires attended by public fire departments that caused 23,100 civilian injuries. Fire losses included $8.6 billion in property damage. While there has been a steady and significant decline in fires, deaths, and injuries, the numbers are still unacceptably high. The United States has one of the worst fire records in the world.

According to the NFPA, several strategies have helped reduce the overall fire death toll in the U.S. and will continue to facilitate future declines. These strategies include:

- More widespread public fire safety and prevention education
- Increased use, testing and maintenance of smoke alarms, and developing and practicing home fire escape plans
- Greater use of more fire-safe home products
- Increased attention to the needs of high-risk groups such as the young, older adults, and low-income communities.

Part of the strategy for improved fire prevention and safety has included education about the benefits and use of fire extinguishers. Businesses, office and public buildings, and industrial manufacturing facilities once were the only places with portable fire extinguishers. Now fire extinguishers are specially designed for cars, boats, and aircraft. Used properly, an extinguisher can limit flame and smoke damage and can conceivably even save a building, business, or home. It is estimated that over 75% of American homes have at least one fire extinguisher.

The three basic configurations of fire extinguishers are hand-held portable, wheeled-portable, and fixed automatic systems. Portable fire extinguishers are designed for small, incipient, controllable fires. The extinguishers are powered by internal pressure, and are labeled indicating the type of fire for which they should be used. Using the wrong extinguisher or using it improperly can spread the fire, or cause personal injury or more serious consequences.

New Technology – The Adiabatic Expansion Nozzle

A scientist at the FAA's William J. Hughes Technical Center has designed a nozzle that will allow a high-pressure fire-fighting agent to undergo staged expansion and use the heat of vaporization to chill the liquid agent entering the device. The two agents studied were CO_2 and trifluoromethane (HFC-3). Any candidate agent that is a gas under ambient conditions, but is stored under pressure can be used with this device.

The Adiabatic Expansion Nozzle is a device that attaches to the pressurized extinguisher cylinder. It extends the usefulness of many fire extinguishing compounds such as carbon dioxide (CO_2) and halon alternative agents.

Description of Technology

Extinguishing agents have generally been categorized in terms of how the agent is to be used.

- **Total flood applications** are those where the agent is discharged to raise the overall concentration of agent in the protected space until fire suppression or extinguishment is achieved. Typical areas where these applications would be used are computer rooms or aircraft engine nacelles.
- **Streaming applications** are those where the agent is discharged directly onto a fire, such as with hand-held extinguishers and large fire-fighting apparatus. Generally, the application is determined by the vapor pressure of the candidate agent.

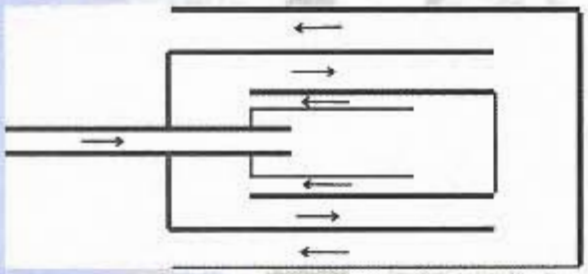
Agents that are at or near their boiling point at room temperature are suitable for streaming applications, while those with a low boiling temperature and high vapor pressure tend to dissipate before reaching the base of a fire. Low boiling agents tend to be limited to total flood applications. Lowering the temperature of an extinguisher would have the effect of allowing total flood agents to be used as streaming agents. It is not practical to store fire extinguishers in a refrigerator/freezer until needed. Achieving this goal would, however, mean that only a single agent would need to be purchased for both types of fire-fighting applications.

How It Works

This nozzle is connected to a fire extinguisher that allows the use of fire-fighting liquids with high vapor pressure compounds not normally suitable for streaming applications. The nozzle is composed of a primary expansion stage and one or more secondary expansion stages for the liquid; the flow is redirected after each secondary expansion stage so that it goes over the conduit that comprises the previous expansion stage. As it goes over the conduit, it extracts heat from the flow within the conduit. Thus, the flow is cooled by expansion in each stage, as well as by heat transfer from stage to stage; during this process it becomes a mixed gas/liquid/solid flow. The flow from the last secondary expansion stage also comes in contact with the inlet conduit to the nozzle. After a number of stages, the flow has been cooled down to the point where a greater part of it becomes a solid—in the case of carbon dioxide—and the flow exits the nozzle as a low temperature mix of gas and solid

particles. In the case of HFC-23, the liquid is chilled to the point that the flow exits the nozzle as a low-pressure aerosol.

The following is a schematic of the Adiabatic Expansion Nozzle.



Classes of Fires and Extinguishers

Fires are separated into four classes:

- **Class A**—involves ordinary combustibles such as trash, paper, wood, cloth, many plastics, and most rubbers. These fires normally occur in homes, offices, or businesses. Class A fires are extinguished by lowering their temperatures with a water or water-based extinguisher, or by coating the combustibles with a multipurpose dry chemical.
- **Class B**—involves flammable liquids such as oil, gasoline, kerosene, grease, tar, lacquer, solvent, or oil-based paint. This type of fire commonly occurs in the kitchen, garage, manufacturing plants, or warehouses. Class B fire can be extinguished by smothering it. The extinguisher gives a blanketing flame-interrupting effect. The entire surface of flaming liquid must be covered to ensure that the fire is extinguished.
- **Class C**—involves fires in energized electrical equipment such as computers, monitors, wiring, fuse boxes, circuit breakers, and appliances. Class C fires are extinguished with a nonconducting extinguishing agent to prevent electric shock. Power must be shut off as quickly as possible.
- **Class D**—involves combustible metals such as chips, turnings, and shavings from magnesium, potassium alloys, etc. Class D fires are put out with dry powder compounds from a specially designated extinguisher.

In addition, although halon production has been banned, recycled halon can still be used to service or recharge extinguishers. An exemption has been granted for commercial aircraft because of the possible catastrophic results of a fire during flight.

The Adiabatic Expansion Nozzle is a device that attaches to a pressurized gas cylinder and extends the usefulness of fire extinguishing compounds such as carbon dioxide (CO_2) and halon alternative agents.

Carbon Dioxide Fire Extinguishers

CO_2 is an agent that is used for both hand-held extinguishers and total flood systems. In a hand-held extinguisher, CO_2 is certified for Class B (i.e., flammable liquids) and Class C (i.e., electrical) fires only. It is not suitable for Class A fires such as wood or paper, primarily because, similar to total flood agents, CO_2 dissipates rapidly and the fire is prone to reignition from smoldering embers. Carbon dioxide is under such high pressure that discharging the extinguishers may tend to spread a fire by blowing bits of flaming wood or paper (embers) from the localized fire site. The high exit velocity of CO_2 blows out a fuel fire much like a person would a candle flame—by separating the flame front from the fuel vapor.

Carbon dioxide is rather unusual as a chemical compound in that, at ordinary room pressure, it exits as only a gas or solid. Most compounds make a transition from solid to liquid to gas as temperature increases, such as ice to water to steam. Carbon dioxide exists as a solid at -79^{O} but, rather than melting to form a liquid, it transitions directly into the gas phase (sublimation). It exists as a liquid at room temperature inside the compressed gas cylinder with a vapor pressure of 830 pounds per square inch (psi).

When CO_2 total flood systems discharge, the protected space undergoes a rapid chilling. The agent continues to discharge into the expansion space inside the nozzle that was chilled by the vaporizing liquid that previously entered this space. In the case of hand-held CO_2 extinguishers, the high-pressure liquid blasts out of the discharge horn as a mixture of solid, liquid and gas. However, due to the temperature of the surroundings, it rapidly changes to all gas.

It is reasoned that the extinguisher would be more effective if the liquid CO_2 were converted into solid because:

- It would be colder and have the physical effect of lowering the vapor pressure of a liquid fuel.
- The exit velocity of the fire-fighting agent would be reduced and have more utility for Class A (wood, paper) fires.
- As a solid the agent would remain on the surface continuing to suppress reignition of the fire.

Device is Suitable for Halon Alternative Agents

The Adiabatic Expansion Nozzle replaces the regular nozzle on a fire extinguisher for the purpose of extending the usefulness of fire extinguishing compounds such as Halon alternative agents. This device uses the latent heat of vaporization of the agent to reduce the temperature and pressure of the agent emerging from the fire extinguisher. Rather than emerging from an extinguisher as a high-pressure gas, the agent is discharged as a very cold liquid or, in the case of CO_2, as a solid (dry ice). This allows fire-fighting agents previously considered for total flood applications only to behave like steaming agents, making them suitable for hand-held applications.

Technical Benefits

This technology is unique in that the nozzle provides the following beneficial attributes:

- Can be used with high vapor pressure compounds to make them behave like streaming agents.
- Does not have an objectionably high exit velocity.
- Can be used in a substantially closed compartment.
- Produces a mixed gas/solid output or low-pressure gas/liquid output.

These attributes provide the ability to fight fires with dry ice rather than gaseous CO_2, lowering the discharge pressure and exposure to potentially asphyxiating levels of gas in total flood applications.

Potential Fields of Use

The Adiabatic Expansion Nozzle may be used on hand-held portable and wheeled-portable CO_2 and certain alternative halon fire extinguishers such that they could be recommended for the extinguishment of Class A, B, and C fires. This nozzle could be used on extinguishers designed for businesses, manufacturing facilities, public buildings, boats, cars, and private residences. The device can also be used in the cargo hold of aircraft for fire suppression.

Employing the Adiabatic Expansion Nozzle would allow carbon dioxide to be used to extinguish Class A fires, making it competitive with water, dry chemicals, and foams.

Intellectual Property Status

United States patent No. 6,116,049 has been issued for this technology.

Market Analysis

The market for hand-held portable and wheeled-portable fire extinguishers is quite large. Fire extinguishers are produced for use in business, manufacturing facilities, residences, automobiles, boats/ships, public buildings, etc.

Hand-held fire extinguishers normally vary in weight from 5 pounds to 20 pounds per unit. Any extinguisher larger than 20 pounds should be wheeled. Hand-held portable fire extinguishers can be either disposable or rechargeable and range in price from approximately $30 to $400 per unit, depending on the size of the extinguisher, the extinguishing agent, and whether the unit is disposable or rechargeable. Wheeled fire extinguishers range in size from 50 to 150 pounds and cost from $350 to more than $1,000 per unit, depending on the size of the extinguisher and the extinguishing agent. It is estimated that the cost of the Adiabatic Expansion Nozzle will constitute only a small percentage of the total cost of the fire extinguisher.

It is anticipated that the fire extinguisher market will continue to grow, primarily in the residential market. During 1998, five hundred and forty-five people died in highway vehicle fires, an increase of 21% from the previous year. Due to education, more people are purchasing fire extinguishers for their automobiles. In addition, legislation has been passed requiring fire extinguishers to be placed in trucks and other commercial vehicles, causing this market segment to grow rapidly. In addition, the number of fire extinguishers purchased for use on boats has significantly increased. Due to the nature of this technology, the Adiabatic Expansion Nozzle can be retrofitted on existing systems with conventional nozzles. This factor would also increase the market size.

Foreign Markets

Although no data exist on the size of the foreign market for the Adiabatic Expansion Nozzle, it is anticipated that the market size could be significant. Most foreign countries are actively involved in fire prevention and safety. As a result, sales of fire extinguishers have increased.

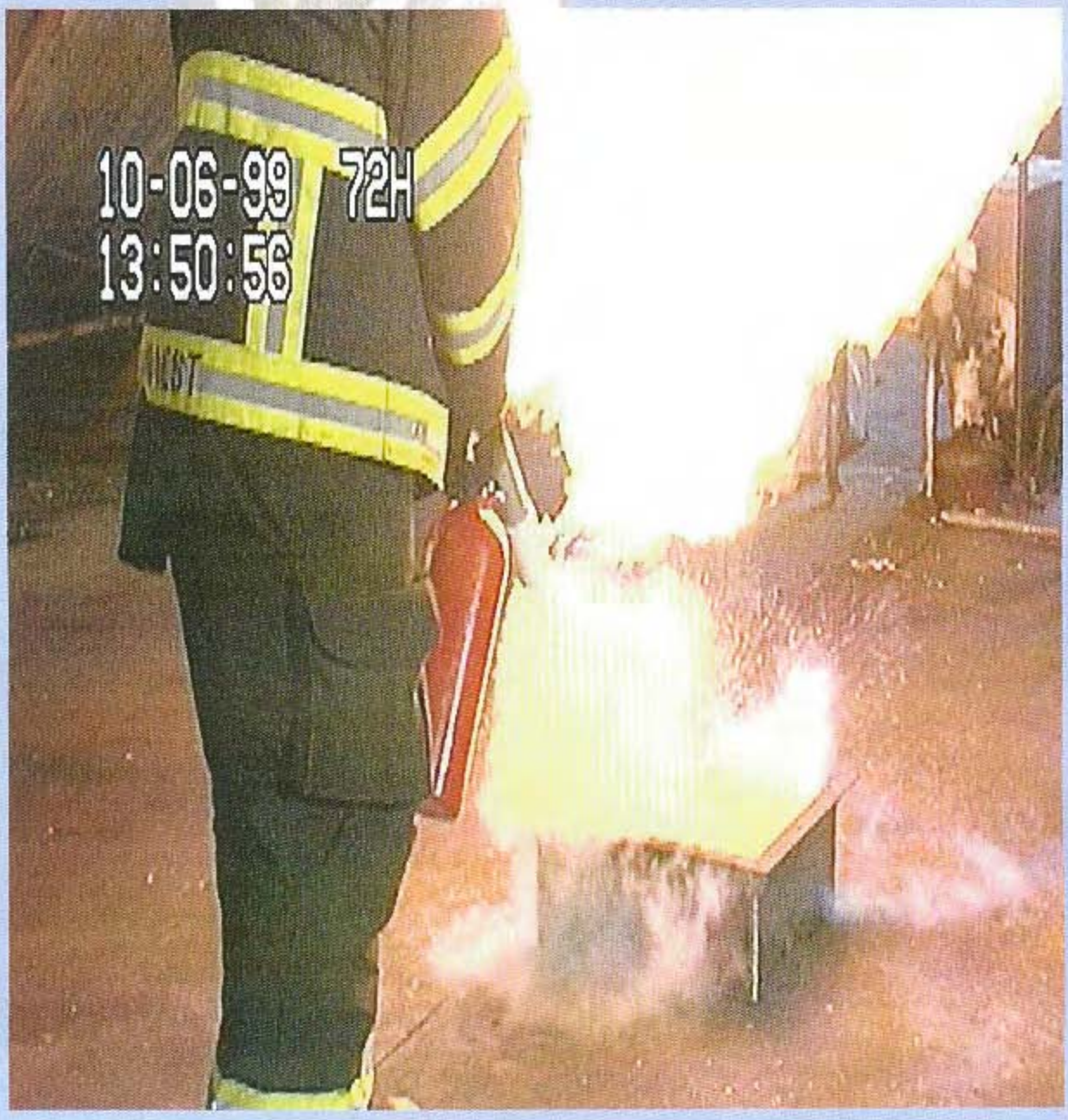
Summary

This technology would be used only on fire extinguishers that utilize CO_2 or certain halon substitute chemicals as the extinguished agent. This would allow these fire extinguishers to be used on Class A, B, and C fires, which would provide a sales advantage in that the user would need only one type of extinguisher for protection from the three common types of fires.

Prototypes of the Adiabatic Expansion Nozzle have been designed, built, and tested with excellent results. A prototype nozzle was attached to a hand-held conventional cylinder of compressed liquid CO_2 to produce solid carbon dioxide fluff for fire-fighting purposes. This system effectively suppressed a Class A fire in less time than a Class A approved fire extinguisher. With the new nozzle, the fire extinguisher lasted twice as long as a fire extinguisher of the same capacity with a conventional nozzle.

Conventional CO2 Extinguisher with Typical Nozzle

Conventional CO2 Extinguisher Fitted with Adiabatic Nozzle



Fire Fighter Using CO_2 Prototype
Adiabatic Expansion Nozzle